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(54) Liquid crystal display device.

(57) Picture inversion in display devices, based on the twisted nematic effect is prevented by choosing a twist angle ψT in such a way that $40° < \psi T < 90°$, while it holds for the angle α between the direction of polarization of one of the polarizers and the associated direction of orientation that:

$30° + \psi T/2 < \alpha < 60° + \psi T/2$.

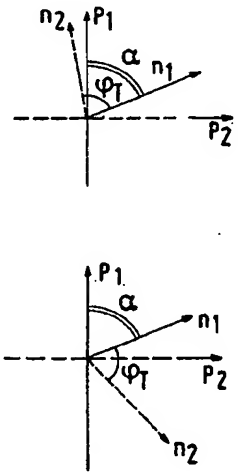

FIG.3

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The invention relates to a liquid crystal display device having a layer of liquid crystal material between two substrates provided with electrodes and orienting layers giving the liquid crystal molecules at the area of the substrates such a preferred direction that the liquid crystal material has a twist angle ψT across the thickness of the layer, said device being further provided with mutually substantially perpendicular polarizers at both sides of the layer of liquid crystal material.

Such a device can be used, for example, in LCD television, but also in datagraphic display devices.

A device of the above-mentioned type is described, for example, in DE-A 0,264,667. This application describes how liquid crystal material having a smaller twist angle ψT, for example, between 10° and 80° for adjusting grey scales is preferred to material having large twist angles (90° or more) which are suitable for high multiplex ratios. At low values of $d.\Delta n$ (d: thickness of the layer of liquid crystal material, Δn: birefringence or optical anisotropy) and suitably chosen states of polarization, such a device provides a good contrast and little discoloration.

A drawback occurring notably in the case of a twist angle of 90° or more is the fact that the contrast in crossed polarizers is angle-dependent around the normal on a front face of the display device and is considerably lower in one quadrant. Moreover, when changing the viewing angle, picture inversion occurs in the quadrant where the highest contrast is obtained due to the specific shape of the transmission/voltage characteristic in the associated viewing direction.

The present invention has for its object to provide a picture display device of the type described in the opening paragraph which does not have said picture inversion. Such a device is characterized in that it holds for the angle ψT that $40° < \psi T < 90°$ and in that it holds for the angle α between the direction of polarization of one of the polarizers and the direction of orientation at the area of said polarizer that $30° + \psi T/2 < \alpha < 60° + \psi T/2$. ψT is preferably chosen to be between 70° and 85°. Lower values of ψT lead to a gradual transmission/voltage characteristic curve so that excessively high drive voltages are required. Due to the chosen value of α there will be a greater contrast at a given ψT and at the same drive voltages, while the color neutrality is substantially maintained.

Optimum results are obtained when a value of between 0.4 and 0.8 is chosen for the optical path length $d.\Delta n/\lambda$ (d: thickness of the liquid crystal layer, Δn: birefringence, λ: wavelength of the light used).

A liquid crystal cell of said parameters is particularly suitable for the so-called active drive mode. A display device suitable for this purpose is characterized in that it further comprises a cross-bar system of rows and columns with switches at the area of the crossings, via which switches voltages are applied to the electrodes.

Various aspects of the invention will now be described in greater detail with reference to an embodiment and the drawing.

Fig. 1 shows diagrammatically iso-contrast curves for a liquid crystal display device with $\psi T = 90°$.

Fig. 2 shows two associated transmission/voltage characteristic curves.

Fig. 3 shows some forms of the relationship between the directions of orientation and the directions of polarization P.

Fig. 4 shows two transmission/voltage characteristic curves of a device according to the invention.

Fig. 1 shows two iso-contrast curves for a liquid crystal display device with $\psi T = 90°$ and $d.\Delta n = 0.48\ \mu m$. As is apparent from the Figure, these are non-rotationally symmetrical while the highest contrast values occur in practice in the fourth quadrant ($270 < \psi < 360°$) i.e. the quadrant in which the viewing direction is located along the director in the centre of the cell. However, in this quadrant the transmission/voltage characteristic curve exhibits an angle-dependent behaviour as is further shown in Fig. 2. This Figure shows two transmission/voltage characteristic curves, namely one in a direction perpendicular to the liquid crystal layer and one in the fourth quadrant ($\psi = 315°$) at an angle of θ with respect to the normal ($\theta = 40°$). It is apparent from Fig. 2 that, for example, at the voltage value V_1 a dark or a grey image is observed, dependent on the angle θ. However, for a voltage $V > V_2$ the transmission change, with a variation in θ, proceeds the other way around. Consequently a change of the viewing angle leads to grey scale inversion in this case. More generally, grey scale inversion is observed whenever a transmission/voltage characteristic curve has a dip in the low transmissive portion with respect to the transmission/voltage characteristic for which the grey scales are defined. Contrast changes also occur.

In a display device according to the invention this problem is solved by suitable choices (see Fig. 3) of the twist angle ψT and the angle a between the direction of polarization P_1 on the front face of the device and the direction of orientation n_1 of the liquid crystal molecules at the area of this front face. P_2 and n_2 represent the direction of polarization and the direction of orientation at the area of the rear face. The directions n_1 and n_2 define the twist angle ψT. P_1 and P_2 are chosen to be per-

pendicular with respect to each other.

Such a device yields the transmission/voltage characteristic curve of Fig. 4 for ψT = 70° and d.Δn = 0.49 μm for different viewing angles. Since the two curves do not exhibit a dip, the problems as described with reference to Fig. 2 no longer occur.

The value of d.Δn/λ may vary between 0.40 and 0.80 dependent on ψT without the achieved advantages being lost, while also a good color neutrality is maintained. In this case λ is dependent on the use. In the case of irradiation with monochrome light, as in projection applications with three light sources, the peak wavelength of the used light is preferably chosen. In the case of irradiation with white light, an average wavelength is chosen.

Claims

1. A liquid crystal display device having a layer of liquid crystal material between two substrates provided with electrodes and orienting layers giving the liquid crystal molecules at the area of the substrates such a preferred direction that the liquid crystal material has a twist angle ψT across the thickness of the layer, said device being further provided with mutually substantially perpendicular polarizers at both sides of the layer of liquid crystal material, characterized in that it holds for the angle ψT that $40° < \psi T < 90°$ and in that it holds for the angle α between the direction of polarization of one of the polarizers and the direction of orientation at the area of said polarizer that:

   $30° + \psi T/2 < \alpha < 60° + \psi T/2$.

2. A liquid crystal display device as claimed in Claim 1, characterized in that $70° < \psi T < 85°$.

3. A liquid crystal display device as claimed in Claim 1 or 2, characterized in that it holds for the product of the thickness d of the liquid crystal layer and the birefringence Δn that:
   $0.4 < d.\Delta n/\lambda < 0.8$, in which λ is either the peak wavelength of a substantially monochrome light source associated with the display device or the average wavelength of a light source associated with the device.

4. A liquid crystal display device as claimed in Claim 1, 2 or 3, characterized in that it further comprises a cross-bar system of rows and columns with switches at the area of the crossings, via which switches voltages are applied to the electrodes.

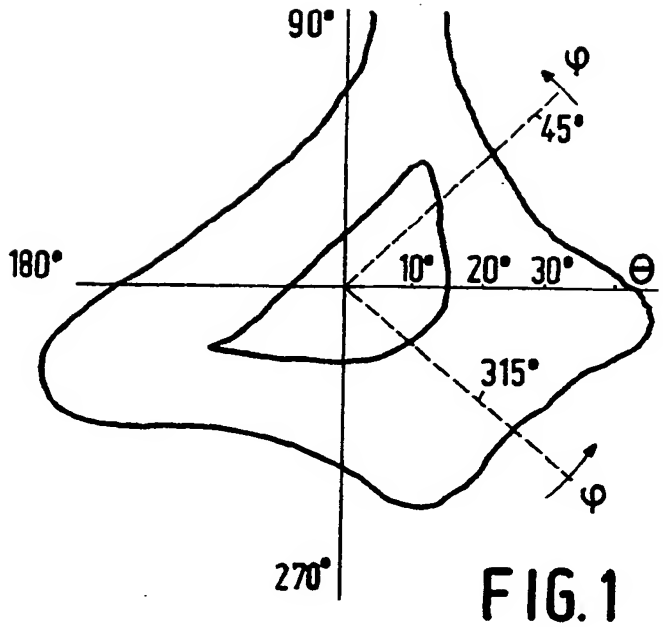
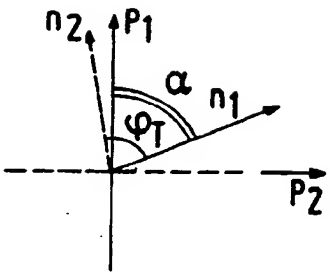


FIG. 1



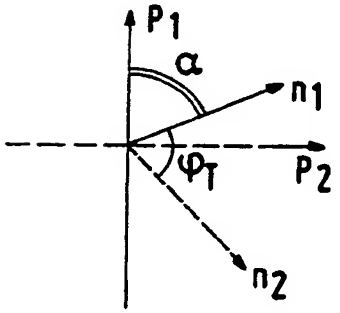


FIG. 3

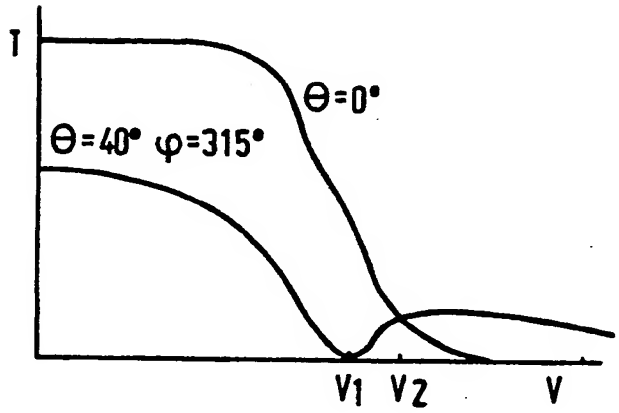


FIG. 2

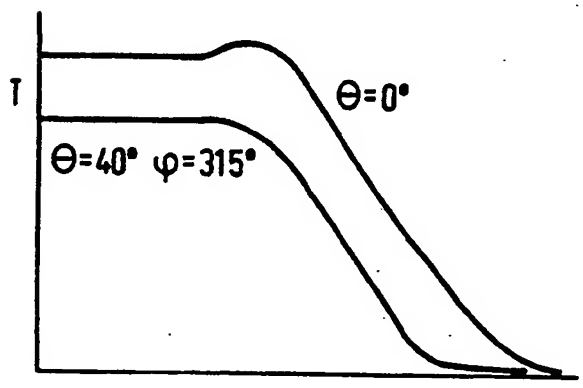


FIG. 4

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EUROPEAN SEARCH REPORT

Application Number

EP 91 20 0611

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A,D	EP-A-0 264 667 (HOFFMAN-LA ROCHE) * Page 3, lines 22-39 *	1-4	G 02 F 1/137
A	US-A-4 039 252 (MIZUNO) * Column 1, line 43 - column 4, line 50 *	1	
A	JOURNAL OF APPLIED PHYSICS, vol. 48, no. 4, April 1977, pages 1426-1431, American Institute of Physics; M. GOSCIANSKI: "Optical characteristics of twisted nematic liquid crystals: Application to the improvement of the scanning capability in matrix displays" * Chpaters II.C,II.D *	1	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

G 02 F

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	04 July 91	DIOT P.M.L.

CATEGORY OF CITED DOCUMENTS

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